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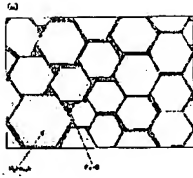
(71)Applicant : SUMITOMO SPECIAL
METALS CO LTD

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(72)Inventor : KANEKIYO HIROKAZU
MITSUGI TOSHIO

(54) RAPIDLY COOLED ALLOY FOR NANO-COMPOSITE MAGNET AND
PRODUCTION METHOD THEREFOR



(57)Abstract:

PROBLEM TO BE SOLVED: To provide a rapidly cooled alloy having a uniform structure and to produce a nano-composite magnet having excellent properties.

SOLUTION: The composition formula of the rapidly cooled alloy is $(\text{Fe}_{1-m}\text{T}_m)_{100-x-y-z}\text{Q}_x\text{R}_y\text{T}_z\text{M}_n$ (wherein T is one or more of elements selected from the group consisting of Co and Ni, Q is one or more kinds of elements selected from the group consisting of B and C, R is one or more of rare earth elements substantially non-containing La and Ce, and M is at least one of metal element selected from the group consisting of Al, Si, V, Cr, Mn, Cu, Zn, Ga, Zr, Nb, Mo, Hf, Ta, W, Pt, Pb, Au, and Ag). The composition ratio x, y and z satisfies $10 < x \leq 20$ atom.%, $6 \leq y < 10$ atom.%, $0.1 \leq z \leq 12$ atom.%, $0 \leq n \leq 10$ atom.% and $0 \leq m \leq 0.5$, respectively. The volume ratio of $\text{R}_2\text{T}_{14}\text{Q}$ -type compound crystalline grains is greater than the volume ratio of $\alpha\text{-Fe}$, the thickness of grain is $< 50 \mu\text{m}$ and $\leq 90 \mu\text{m}$, and the standard deviation of the thickness is $\leq 15 \mu\text{m}$.

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CLAIMS

[Claim(s)]

[Claim 1] an empirical formula -- $100(\text{Fe}_{1-m}\text{Tm})_x\text{-y-zQxRyTizMn}$ (one or more sorts of elements chosen from the group which T becomes from Co and nickel --) One or more sorts of elements chosen from the group which Q becomes from B and C, one or more sorts of rare earth metal elements with which R does not contain La and Ce substantially, M aluminum, Si, V, Cr, Mn, Cu, Zn, Ga, Zr, Nb, It is expressed by at least one sort of metallic elements chosen from the group which consists of Mo, Hf, Ta, W, Pt, Pb, Au, and Ag. The presentation ratio x, and y, z, n and m, respectively $10 < x \leq 20$ atom %, $y < 6 \leq 10$ atom %, $0.1 \leq z \leq 12$ atom %, $0 \leq n \leq 10$ atom %, And the quenching alloy for nano composite magnets whose standard deviation of thickness it is the quenching alloy with which are satisfied of $0 \leq m \leq 0.5$, and the rate of a volume ratio of

R2T14Q mold compound crystal grain is larger than the rate of a volume ratio of alpha-Fe, average thickness exceeds 50 micrometers, it is 90 micrometers or less, and is 15 micrometers or less.

[Claim 2] The quenching alloy for nano composite magnets according to claim 1 which contains said R2T14Q mold compound crystal grain more than the whole 50 volume % at the rate of a volume ratio.

[Claim 3] The quenching alloy for nano composite magnets according to claim 1 or 2 whose diameter of average crystal grain of said R2T14Q mold compound crystal grain is 150nm or less.

[Claim 4] an empirical formula -- $100(\text{Fe}_{1-m}\text{Tm})_{-x-y-z}\text{QxRyTizMn}$ (one or more sorts of elements chosen from the group which T becomes from Co and nickel --) One or more sorts of elements chosen from the group which Q becomes from B and C, one or more sorts of rare earth metal elements with which R does not contain La and Ce substantially, M aluminum, Si, V, Cr, Mn, Cu, Zn, Ga, Zr, Nb, It is expressed by at least one sort of metallic elements chosen from the group which consists of Mo, Hf, Ta, W, Pt, Pb, Au, and Ag. The process for which the presentation ratio x, and y, z, n and m prepare the molten metal of an alloy which satisfies $10 < x \leq 20$ atom %, $y < 6 \leq 10$ atom %, $0.1 \leq z \leq 12$ atom %, $0 \leq n \leq 10$ atom %, and $0 \leq m \leq 0.5$, respectively, Said alloy molten metal is contacted at the above supply rate by 1.5kg/to the front face of the rotating cooling roller. The cooling process which produces the quenching alloy whose standard deviation of thickness the rate of a volume ratio of R2T14Q mold compound crystal grain is larger than the rate of a volume ratio of an alpha-Fe phase, and average thickness exceeds 50 micrometers, it is moreover 90 micrometers or less, and is 15 micrometers or less by it, The manufacture approach of the quenching alloy for nano composite magnets to include.

[Claim 5] Said cooling process is the manufacture approach including the process which turns said alloy molten metal to the front face of said cooling roller, and injects it using the nozzle orifice exceeding the bore of 1mm according to claim 4.

[Claim 6] Said cooling process is the manufacture approach according to claim 4 which supplies said alloy molten metal on a guidance means by which a slideway receives horizontally and forms the include angle of 1-80 degrees, and includes the process which moves said alloy molten metal to a surface of action with said cooling roller.

[Claim 7] Said cooling process is the manufacture approach according to claim 6 which includes dividing the flow of said alloy molten metal into two or more articles, and adjusting the width of face of a monograph in predetermined magnitude along the direction of an axis of said cooling roller with said guidance means.

[Claim 8] Production of said quenching alloy is the manufacture approach given in either of claims 4-6 performed in a reduced pressure controlled atmosphere.

[Claim 9] The pressure of said controlled atmosphere is the manufacture approach according to claim 8 currently adjusted by 100 or less kPa of 30 or more kPas pressures.

[Claim 10] The manufacture approach given in either of claims 4-9 which carry out the rate of a volume ratio of said R2T14Q mold compound crystal grain in said cooling process more than 50 volume % of said quenching alloy.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the quenching alloy used for manufacture of the iron machine rare earth alloy magnet which has two or more ferromagnetic phases especially about the quenching alloy for the permanent magnet used suitable for various motors or an actuator.

[0002]

[Description of the Prior Art] In recent years, in the device for household electric appliances, OA equipment, electronic autoparts, etc., much more high-performance-izing and small lightweight-ization are demanded. Therefore, about the permanent magnet used for these devices, it is required that making the engine-performance tare quantitative ratio as the whole magnetic circuit into max should be called for, for example, a residual magnetic flux density B_r should use the permanent magnet more than 0.5T (tesla). However, depending on the conventional comparatively cheap hard ferrite magnet, a residual magnetic flux density B_r cannot be carried out more than 0.5T.

[0003] As a permanent magnet which has current and the high residual magnetic flux density B_r beyond 0.5T, the Sm-Co system magnet produced by powder-metallurgy processing is known. Except a Sm-Co system magnet, the Nd-Fe-B system magnet produced by powder-metallurgy processing and the Nd-Fe-B system quenching magnet produced by the melt quenching method can demonstrate the high residual magnetic flux density B_r . The former Nd-Fe-B system magnet is indicated by JP,59-46008,A, and the latter Nd-Fe-B system quenching magnet is indicated by JP,60-9852,A.

[0004]

[Problem(s) to be Solved by the Invention] however, any of Sm and Co from which a Sm-Co system magnet serves as a raw material -- although -- since it is expensive, it has the fault that a magnet price is high.

[0005] In the case of a Nd-Fe-B system magnet, since it is included, using cheap Fe as a principal component (60 % of the weight - about 70% of the weight of the whole), compared with a Sm-Co system magnet, it is cheap, but there is a problem that the costs which the production process takes are high. One of the reasons why production process costs are high is that a large-scale facility and a great process are needed for the separation purification and the reduction reaction of Nd for which a content occupies ten whole atoms % - 15 atom % extent. Moreover, when based on powder-metallurgy processing, the number of production processes surely increases.

[0006] On the other hand, since the Nd-Fe-B system quenching magnet manufactured by the melt quenching method is obtained at the comparatively easy process of a dissolution process -> liquid cooling process -> heat treatment process, it has the advantage that process costs are cheap compared with the Nd-Fe-B system magnet by powder-metallurgy processing. However, since it is necessary to mix with resin the magnet powder produced from the quenching alloy, and to form a bond magnet in order to obtain a bulk-like permanent magnet when based on a melt quenching method, the filling factor (rate of a volume ratio) of the magnet powder occupied to the fabricated bond magnet is at most about 80%. Moreover, the quenching alloy produced with the melt quenching method is isotropy magnetically.

[0007] From the above reason, it has the problem that the Nd-Fe-B system quenching magnet manufactured using the melt quenching method has low Br compared with the Nd-Fe-B system sintered magnet of the anisotropy manufactured with powder-metallurgy processing.

[0008] As the technique of improving the property of a Nd-Fe-B system quenching magnet, it is effective to add complexly at least one sort of elements chosen from the group which consists of Zr, Nb, Mo, Hf, Ta, and W, and at least one sort of elements chosen from the group which consists of Ti, V, and Cr as indicated by JP, 1-7502, A. Although coercive force HcJ and corrosion resistance improve by addition of such an element, the effective method of improving a

residual magnetic flux density B_r is not learned besides improving the consistency of a bond magnet.

[0009] In the case of the Nd-Fe-B system magnet, the concentration of rare earth elements has a presentation low in comparison, i.e., the near presentation of Nd_{3.8}Fe_{77.2}B₁₉ (atomic %), and the magnet ingredient which makes a Fe₃B mold compound the main phase is proposed (J.de Phys, such as R.Coehoorn, C 8 and 1998, 669-670 pages). By performing heat-of-crystallization processing to the amorphous alloy produced with the melt quenching method, this permanent magnet ingredient has the metastable structure formed from the fine crystal aggregate with which the Nd₂Fe₁₄B phase which is Fe₃B phase and hard magnetism which are soft magnetism is intermingled, and is called the "nano composite magnet." Although having the high residual magnetic flux density B_r beyond 1T is reported about such a nano composite magnet, the coercive force H_{cJ} is comparatively as low as 160 kA/m - 240 kA/m. Therefore, use of this permanent magnet ingredient is restricted to the application from which the magnetic operating point becomes one or more.

[0010] Moreover, various metallic elements are added into the raw material alloy of a nano composite magnet. although the attempt which raises magnetic properties is made (JP,3-261104,A --) A U.S. Pat. No. 4,836,868 number, JP,7-122412,A, The international public presentation official report WO 03/03403 of international application, wcChan, and et.al."THE EFFECTS OF REFRACTORY METALS ON THE MAGNETIC PROPERTIES OF Alpha-Fe/R₂Fe₁₄B-TYPE NANOCOMPOSITES", IEEE, Trans.Magn.No.5, INTERMAG.99, Kyongju, Korea pp.3265-3267, 1999, Sufficient "characteristic value per cost" is not necessarily acquired.

[0011] This invention is made in view of the above-mentioned situation, and the place made into the purpose is to offer the quenching alloy for manufacturing the nano composite magnet which was excellent in magnetic properties by low cost.

[0012]

[Means for Solving the Problem] The quenching alloy for nano composite

magnets by this invention an empirical formula -- $100(\text{Fe}_{1-m}\text{Tm})_x\text{y-zQxRyTizMn}$ (one or more sorts of elements chosen from the group which T becomes from Co and nickel --) One or more sorts of elements chosen from the group which Q becomes from B and C, one or more sorts of rare earth metal elements with which R does not contain La and Ce substantially, M aluminum, Si, V, Cr, Mn, Cu, Zn, Ga, Zr, Nb, It is expressed by at least one sort of metallic elements chosen from the group which consists of Mo, Hf, Ta, W, Pt, Pb, Au, and Ag. The presentation ratio x, and y, z, n and m, respectively $10 < x \leq 20$ atom %, $y < 6 \leq 10$ atom %, $0.1 \leq z \leq 12$ atom %, $0 \leq n \leq 10$ atom %, And the rate of a volume ratio of R2T14Q mold compound crystal grain is larger than the rate of a volume ratio of alpha-Fe, moreover, it is the quenching alloy with which are satisfied of $0 \leq m \leq 0.5$, and the standard deviation of thickness is [average thickness exceeds 50 micrometers, it is 90 micrometers or less, and] 15 micrometers or less.

[0013] In a desirable operation gestalt, said R2T14Q mold compound crystal grain is contained more than the whole 50 volume % at the rate of a volume ratio.

[0014] In a desirable operation gestalt, the diameter of average crystal grain of said R2T14Q mold compound crystal grain is 150nm or less. The desirable diameter of average crystal grain is 70nm or less.

[0015] The manufacture approach of the quenching alloy for nano composite magnets by this invention an empirical formula -- $100(\text{Fe}_{1-m}\text{Tm})_x\text{y-zQxRyTizMn}$ (one or more sorts of elements chosen from the group which T becomes from Co and nickel --) One or more sorts of elements chosen from the group which Q becomes from B and C, one or more sorts of rare earth metal elements with which R does not contain La and Ce substantially, M aluminum, Si, V, Cr, Mn, Cu, Zn, Ga, Zr, Nb, It is expressed by at least one sort of metallic elements chosen from the group which consists of Mo, Hf, Ta, W, Pt, Pb, Au, and Ag. The process for which the presentation ratio x, and y, z, n and m prepare the molten metal of an alloy which satisfies $10 < x \leq 20$ atom %, $y < 6 \leq 10$ atom %, $0.1 \leq z \leq 12$ atom %, $0 \leq n \leq 10$ atom %, and $0 \leq m \leq 0.5$, respectively, Said

alloy molten metal is contacted at the above supply rate by 1.5kg/to the front face of the rotating cooling roller. By it, more greatly than the rate of a volume ratio of alpha-Fe, moreover thickness exceeds 50 micrometers and the rate of a volume ratio of R2T14Q mold compound crystal grain includes the cooling process which produces the quenching alloy whose standard deviation of thickness it is 90 micrometers or less and is 15 micrometers or less.

[0016] In a desirable operation gestalt, said cooling process includes the process which turns said alloy molten metal to the front face of said cooling roller, and injects it using the nozzle orifice exceeding the bore of 1mm.

[0017] In a desirable operation gestalt, said cooling process supplies said alloy molten metal on a guidance means by which a slideway receives horizontally and forms the include angle of 1-80 degrees, and includes the process which moves said alloy molten metal to a surface of action with said cooling roller.

[0018] In a desirable operation gestalt, said cooling process includes dividing the flow of said alloy molten metal into two or more articles, and adjusting the width of face of a monograph in predetermined magnitude along the direction of an axis of said cooling roller with said guidance means.

[0019] In a desirable operation gestalt, production of said quenching alloy is performed in a reduced pressure controlled atmosphere.

[0020] The pressure of said controlled atmosphere is adjusted in the desirable operation gestalt by 100 or less kPa of 30 or more kPas pressures.

[0021] In a desirable operation gestalt, the rate of a volume ratio of said R2T14Q mold compound crystal grain is carried out in said cooling process more than 50 volume % of said quenching alloy.

[0022]

[Embodiment of the Invention] The quenching alloy for nano composite magnets by this invention is produced by cooling and solidifying the molten metal of the rare earth-iron-boron system alloy containing Ti. After this quenching alloy is heated if needed, it is ground and is used for manufacture of a bond magnet etc. as magnet powder.

[0023] When it explains to a detail more, the quenching alloy of this invention an empirical formula -- $100(\text{Fe}_{1-m}\text{Tm})_x\text{-y-zQxRyTizMn}$ (one or more sorts of elements chosen from the group which T becomes from Co and nickel --) One or more sorts of elements chosen from the group which Q becomes from B and C, one or more sorts of rare earth metal elements with which R does not contain La and Ce substantially, M aluminum, Si, V, Cr, Mn, Cu, Zn, Ga, Zr, Nb, It is expressed by at least one sort of metallic elements chosen from the group which consists of Mo, Hf, Ta, W, Pt, Pb, Au, and Ag. The presentation ratio x, and y, z, n and m satisfy $10 < x \leq 20$ atom %, $y < 6 \leq 10$ atom %, $0.1 \leq z \leq 12$ atom %, $0 \leq n \leq 10$ atom %, and $0 \leq m \leq 0.5$, respectively. Moreover, there are more rates of a volume ratio of $\text{R}_2\text{T}_{14}\text{Q}$ mold compound crystal grain than the rate of a volume ratio of $\alpha\text{-Fe}$, and average thickness exceeds 50 micrometers and it has the description at the point that it is 90 micrometers or less and the standard deviation of thickness is 15 micrometers or less.

[0024] The magnet alloy produced using the quenching alloy of this invention has the nano composite structure mutually isolated by the thin film (20nm or less in average thickness) and/or thin particle (the direction size of a major axis: 1-50nm) of iron machine boride whose $\text{R}_2\text{T}_{14}\text{Q}$ mold compound crystal grain which is a hard magnetism phase is a soft magnetism phase, as shown in drawing 1 . In such a nano composite magnet, $\text{R}_2\text{T}_{14}\text{Q}$ mold compound crystal grain can combine with a soft magnetism phase magnetically by the exchange interaction, and can demonstrate the magnet property which was excellent as an exchange spring magnet.

[0025] If concentration of rare earth elements R is made lower than 10 atom % extent, since the rate of a volume ratio of the $\text{R}_2\text{Fe}_{14}\text{B}$ mold compound phase which bears hard magnetism not only decreases, but $\alpha\text{-Fe}$ generally deposits in advance of an $\text{R}_2\text{Fe}_{14}\text{B}$ mold compound phase, it becomes easy to make it big and rough. Although the magnetization as the final whole magnet increases since the magnetization of $\alpha\text{-Fe}$ is high, the square shape nature and coercive force of a demagnetization curve will decline by big and rough $\alpha\text{-Fe}$

being included. Although the attempt to which make detailed alpha-Fe which is easy to make it big and rough by making all crystal phases fine, and coercive force is made to increase by addition of a metallic element occurred conventionally, the coercive force acquired was inadequate.

[0026] B concentration sets [the concentration of rare earth elements R] this invention person under 10 atom % to the field of 10 - 20 atom % (preferably ten to 17 atom %). It found out that an R2T14Q mold compound crystal could be deposited preferentially, and iron machine boride could be further deposited in the grain boundary of an R2T14Q mold compound crystal, controlling a deposit and big and rough-ization of alpha-Fe, when Ti of optimum dose was added. The fact that an R2T14Q mold compound crystal can be preferentially deposited by Ti addition, controlling a deposit and big and rough-ization of alpha-Fe is indicated by the patent No. 3264664 official report by these people.

[0027] However, since the property of the above-mentioned nano composite magnet was very sensitive to organization, when quenching conditions changed, the organization of a quenching alloy ununiformity-ized it and it had the problem that a magnet property final as the result tends to deteriorate. When saying more concretely and the cooling rate became slow too much with some quenching alloys even if it maintained uniformly the rotation peripheral velocity and the molten metal amount of supply of a cooling roller, big and rough alpha-Fe might deposit into the part, and the magnet property might deteriorate. It traces that the cause of generating of alpha-Fe made big and rough in this way is in thickness dispersion of a quenching alloy as a result of this invention person's inquiring wholeheartedly, and came to hit on an idea of this invention.

[0028] Generally, in the case of the quenching magnet which has single phase organization, thickness dispersion of a quenching alloy does not have big effect on a magnet property. Especially when producing the quenching alloy which raised the cooling rate of an alloy molten metal and the whole made abbreviation amorphous, even if the thickness of a quenching alloy varies, dispersion in a final magnet property is hardly caused. *****, as for thinking as the reason, the

thickness of an amorphous quenching alloy varies -- the structure of an amorphous organization -- the inside of a quenching alloy -- abbreviation -- it is because it becomes uniform, so it does not have big effect on the alloy organization after heat treatment.

[0029] On the other hand, in this invention, the special quenching alloy with which the detailed crystalline structure occupies 50% or more (preferably 60% or more) of the whole at the rate of a volume ratio is produced. And a cooling rate is made comparatively late and a quenching alloy is produced more thickly. For this reason, if the thickness of a quenching alloy varies by the part, since a cooling rate falls locally, in a thick part, the structure of the crystalline structure will ununiformity-ize relatively. Especially, by this invention, in order to produce the quenching alloy which deposited preferentially R2T14Q mold compound crystal grain by addition of Ti though the alloy molten metal of a presentation by which alpha-Fe deposits and grows more preferentially than an R2T14Q mold compound crystal is used if Ti is not added, it is necessary to equalize the cooling coagulation process in each part of a quenching alloy in a high precision.

[0030] According to the experiment of this invention person, the phenomenon in which the molten metal amount of supply per unit time amount (molten metal supply rate) becomes unstable when an alloy molten metal is injected and quenched using a nozzle orifice with a bore of 1mm or less, and a cooling rate became an ununiformity with the location of a quenching alloy thin band was observed notably, and found out also ununiformity-izing organization in a quenching alloy as a result of the phenomenon. Moreover, it was observed also when the same thing set up the molten metal injection pressure from a nozzle low. Thus, when a quenching alloy organization is uneven, as a result of the powder particle to which a magnet property is inferior in dispersion and magnetic properties in the magnet powder produced by grinding mixing, a final magnet property will be equalized and it will deteriorate. Thus, when the nozzle orifice of size used from the former is used for manufacture of the quenching alloy of this invention, in order that a molten metal may receive resistance from the internal

surface in the path where a nozzle orifice is narrow, the jet velocity and the amount of jet of a molten metal are changed delicately, consequently it is thought that thickness dispersion of a quenching alloy becomes large.

[0031] While this invention person enlarged the rate (supply rate) of the alloy molten metal supplied to a cooling roller compared with the former using the nozzle orifice (preferably bore of 2mm or more) exceeding the bore of 1mm, when limiting the average thickness of a quenching alloy to the 50-micrometer or more range of 90 micrometers or less, he suppressed thickness dispersion of a quenching alloy and found out that the standard deviation was controllable to 15 micrometers or less. And when controlling the standard deviation of quenching alloy thickness to 15 micrometers or less, the organization in a quenching alloy was equalized, and it finds out that a magnet property can be raised and came to hit on an idea of this invention. In addition, the more desirable lower limit of the average thickness of a quenching alloy is 55 micrometers, and a still more desirable lower limit is 60 micrometers. Moreover, the more desirable upper limit of the standard deviation of quenching alloy thickness is 13 micrometers, and is a still more desirable upper limit of 11 micrometers.

[0032] In addition, when the average thickness of a quenching alloy exceeds 50 micrometers, as a result of the configuration of the pulverized powder of an alloy becoming close to a homaxial configuration, the important effectiveness that the filling factor of magnetic powder improves at the process which fabricates a bond magnet is acquired. However, for the improvement in a filling factor, only by enlarging average thickness of a quenching alloy, quenching conditions tend to become unstable and the problem that magnetic properties deteriorate arises. In this invention, it has succeeded in avoiding degradation of magnetic properties by equalizing the organization of a quenching alloy by adjusting the supply rate of an alloy molten metal.

[0033] Hereafter, the desirable operation gestalt of this invention is explained.

[0034] With a [quenching equipment of alloy molten metal] book operation gestalt, a raw material alloy is manufactured using the quenching equipment shown in

drawing 2 , for example. In order to prevent oxidation of the raw material alloy containing the rare earth elements R and Fe which are easy to oxidize, it is desirable to perform an alloy production process in an inert gas ambient atmosphere. As inert gas, rare gas and nitrogen, such as helium or an argon, can be used. In addition, as for nitrogen, it is desirable to use rare gas, such as helium or an argon, in order to tend to react in comparison with rare earth elements R.

[0035] The equipment of drawing 2 held the vacuum or the inert gas ambient atmosphere, and is equipped with the dissolution room 1 and the quenching room 2 of the raw material alloy which can adjust the pressure. Drawing 2 (a) is a whole block diagram, and drawing 2 (b) is some enlarged drawings.

[0036] As shown in drawing 2 (a), the dissolution room 1 is equipped with the fusion furnace 3 which dissolves the raw material 20 blended so that it might become a desired magnet alloy presentation at an elevated temperature, the hot-water-storing container 4 which has the tapping nozzle 5 at the pars basilaris ossis occipitalis, and the combination feeding equipment 8 for supplying a feed ingredient in a fusion furnace 3, controlling atmospheric penetration. The hot-water-storing container 4 stores the molten metal 21 of a raw material alloy, and has the heating apparatus (un-illustrating) which can maintain the tapping temperature on predetermined level.

[0037] The quenching room 2 is equipped with the rotation cooling roller 7 for carrying out the rapid solidification of the molten metal 21 which came out of the tapping nozzle 5.

[0038] In this equipment, the ambient atmosphere in the dissolution room 1 and the quenching room 2 and its pressure are controlled by the predetermined range. Therefore, controlled atmosphere feed hopper 1b, 2b and 8b, and the flueing openings 1a, 2a, and 8a are formed in the suitable part of equipment. Especially flueing opening 2a is connected to the pump in order to control the absolute pressure in the quenching room 2 within the limits of 30kPa(s) - ordinary pressure (atmospheric pressure) (preferably 100 or less kPas). By changing the

pressure of the dissolution room 1, the injection pressure of the molten metal which comes out of a nozzle 5 can be adjusted.

[0039] A fusion furnace 3 can be tilted and pours in a molten metal 21 suitably in the hot-water-storing container 4 through a funnel 6. A molten metal 21 is heated by non-illustrated heating apparatus in the hot-water-storing container 4.

[0040] The tapping nozzle 5 of the hot-water-storing container 4 is arranged at the septum of the dissolution room 1 and the quenching room 2, and makes the front face of a cooling roller 7 in which it is located caudad flow down the molten metal 21 in the hot-water-storing container 4. The diameter of an orifice of the tapping nozzle 5 is set up within the limits of 2.0mm or more 4.0mm or less (for example, 2.8mm). Although a molten metal 21 stops being able to flow easily in the inside of the tapping nozzle 5 and it is easy to cause thickness dispersion of a quenching alloy when the viscosity of a molten metal 21 is large, with this operation gestalt Since the quenching room 2 is held in the pressure condition lower enough than the dissolution room 1 while expanding the diameter of an orifice compared with the former, big differential pressure (differential pressure of 10 or more kPas) is formed between the dissolution room 1 and the quenching room 2, and tapping of a molten metal 21 is performed smoothly. According to the equipment used with this operation gestalt, the supply rate of an alloy molten metal can be set as a part for 1.5-10kg/. If a supply rate exceeds a part for 10kg/, a molten metal quenching rate will become slow and un-arranging [that big and rough alpha-Fe deposits] will arise. The still more desirable supply rate of an alloy molten metal is a part for 2-8kg/.

[0041] As for a cooling roller 7, it is desirable to form from the alloy containing Cu, Fe or Cu, or Fe. If a cooling roller is produced with ingredients other than Cu or Fe, since the detachability over the cooling roller of a quenching alloy will worsen, it is [a possibility that a quenching alloy may coil around a roll] and is not desirable. The diameter of a cooling roller 7 is 300-500mm. The water-cooled capacity of a water cooler established in the cooling roller 7 is computed and adjusted according to the coagulation latent heat and the amount of tapping per

unit time amount.

[0042] [Quenching method] The molten metal 21 of the raw material alloy expressed with the above-mentioned empirical formula is produced first, and it stores in the hot-water-storing container 4 of the dissolution room 1 of drawing 2 . Next, tapping of this molten metal 21 is carried out from the tapping nozzle 5 on the water-cooled roll 7 in a reduced pressure Ar ambient atmosphere, and contact to a cooling roller 7 quenches it, and it is solidified.

[0043] According to the alloy presentation of this invention, in case an alloy molten metal is cooled, the rate of a volume ratio of the R₂T₁₄Q mold compound phase which the R₂Fe₁₄Q phase which is a hard magnetism phase is deposited preferentially, consequently is contained in the quenching alloy of as-cast (before heat treatment) in the high temperature field where nucleation frequency is high can be made 60% or more. In order to obtain such a quenching organization, it is desirable to carry out the cooling rate of an alloy molten metal in 1×10^2 - 10^8 degrees C/second, and it is still more desirable to carry out in 1×10^2 to 1×10^6 degrees C/second.

[0044] The time amount by which the molten metal 21 of an alloy is cooled with a cooling roller 7 is equivalent to time amount after an alloy contacts the periphery front face of the rotating cooling roller 7 until it separates, and between them, the temperature of an alloy falls and will be in a supercooled liquid condition. Then, the alloy of a supercooling condition separates from a cooling roller 7, and flies the inside of an inert atmosphere. As a result of heat's being taken by the controlled atmosphere while the alloy is flying with thin band-like one, the temperature falls further. With this operation gestalt, since the pressure of a controlled atmosphere is set up within the limits of 30kPa(s) - ordinary pressure, the cooling effectiveness by the controlled atmosphere can become strong, and an R₂T₁₄Q mold compound can be deposited and grown up uniformly minutely into an alloy. In addition, when a suitable quantity of Ti is not added in a raw material alloy, in order that alpha-Fe may deposit and grow preferentially, the magnet property finally acquired will deteriorate in the quenching alloy which

passed through a cooling process which was mentioned above.

[0045] With this operation gestalt, in order to adjust roll surface velocity a second within the limits of 10m /or more 30m/second or less and to heighten the secondary-cooling-of-concrete effectiveness by the controlled atmosphere, the quenching alloy which contains a detailed R2T14Q mold compound phase with a mean particle diameter of 70nm or less more than 60 volume % preferably is produced the mean particle diameter of 150 micrometers or less by setting the ambient-gas-pressure force to 30 or more kPas.

[0046] In addition, the quenching method of an alloy molten metal used by this invention is not limited to the above-mentioned piece rolling method, but the strip cast method which is the quenching approach of not performing control of flow by the nozzle orifice may be used for it. When based on the strip cast method, in order not to use a nozzle orifice, a molten metal supply rate is enlarged and there is an advantage of being easy to stabilize. However, it is easy to generate controlled atmosphere contamination between a cooling roller and a molten metal, and the cooling rate by the side of a quenching side may carry out an ununiformity. In order to solve such a problem, it is necessary to make it fall to the range which mentioned above the ambient pressure force of space in which the cooling roller was placed, and to control the contamination of a controlled atmosphere.

[0047] When adopting the strip cast method, it is desirable to use the strip cast equipment shown in drawing 3 . The equipment of drawing 3 is arranged in the chamber which is not illustrated [which can change the interior into the reduced pressure condition in an inert gas ambient atmosphere]. This strip casting equipment is equipped with the chute (guidance means) 45 which leads a molten metal 43 to a cooling roller 47 from the fusion furnace 41 for dissolving an alloy raw material, the cooling roller 47 for making the alloy molten metal 43 supplied from a fusion furnace 41 quench and solidify, and the fusion furnace 41.

[0048] A fusion furnace 41 can supply the molten metal 43 produced by fusing an alloy raw material by the amount of supply of abbreviation regularity to chute 45.

This amount of supply can be adjusted to arbitration by controlling the actuation which leans a fusion furnace 41 etc.

[0049] The peripheral face is formed from the copper thermally conductive good ingredient, for example, a cooling roller 47 has the dimension whose width of face is 15cm - 100cm for the diameter of 30cm - 100cm. A cooling roller 47 can be rotated with a predetermined rotational speed with a non-illustrated driving gear. By controlling this rotational speed, the peripheral velocity of a cooling roller 47 can be adjusted to arbitration. The cooling rate by this strip casting equipment is controllable by choosing the rotational speed of a cooling roller 47 etc. in about 102 degrees C/second - about 105 degrees C [/second] range.

[0050] The field to which it shows the molten metal of chute 45 receives horizontally, and inclines at an include angle (whenever [tilt-angle]) α , and the distance of the point of chute 45 and the front face of a cooling roller is kept at several mm or less. And chute 45 is arranged so that the line which connects the point and core of a cooling roller 47 may receive horizontally and may form an include angle β ($0 \text{ degree} \leq \beta \leq 90 \text{ degrees}$). As for α , it is desirable that it is $1 \text{ degree} \leq \alpha \leq 80 \text{ degrees}$, and it is [whenever / tilt-angle / of chute 45] still more desirable to satisfy the relation it is [relation] $5 \text{ degrees} \leq \alpha \leq 60 \text{ degrees}$. As for an include angle β , it is desirable to satisfy the relation of $10 \text{ degrees} \leq \beta \leq 55 \text{ degrees}$.

[0051] The molten metal 43 supplied on the chute 45 is supplied from the point of chute 45 to the front face of a cooling roller 47, and forms the paddle 46 of a molten metal in the front face of a cooling roller 47.

[0052] As chute 45 can carry out hot water storing of the molten metal 43 supplied continuously temporarily by the predetermined flow rate from a fusion furnace 41, it can be delayed in the rate of flow, and it can rectify the flow of a molten metal 43. If the **** check plate to which flow of the molten metal surface section in the molten metal 43 supplied to the chute 45 is alternatively made as for **** stop ***** is formed, the rectification effectiveness can be raised further. using chute 45 -- the direction of drum length of a cooling roller 47 (the direction

of an axis: perpendicular to space) -- setting -- constant width -- crossing -- abbreviation -- a molten metal 43 can be supplied in the condition of having extended in uniform thickness. By adjusting α whenever [tilt-angle / of the molten metal slideway of chute 45], a molten metal speed of supply can be tuned finely. With the self-weight, a molten metal flows the slideway toward which the chute 45 inclined, and has a momentum component parallel horizontally (X shaft orientations). The rate of flow of a molten metal becomes quick, and momentum also becomes large, so that α is enlarged whenever [tilt-angle / of chute 45].

[0053] In addition to the above-mentioned function, chute 45 also has the function to adjust the temperature of the molten metal 3 just before reaching a cooling roller 47. As for the temperature of the molten metal 43 on chute 45, it is desirable that it is temperature higher 100 degrees C or more than liquidus-line temperature. It is because primary phases, such as TiB₂ which has a bad influence on the alloy property after quenching, may carry out karyogenesis locally, and they may remain after this solidifying when the temperature of a molten metal 43 is too low. Moreover, if molten metal temperature is too low, molten metal viscosity will rise and it will become easy to generate a splash. Although the molten metal temperature on chute 45 is controllable by adjusting the molten metal temperature in the time of pouring into chute 45 from a fusion furnace 41, the heat capacity of chute 45 the very thing, etc., it may form chute heating apparatus if needed.

[0054] As for chute 45, in the edge arranged so that the peripheral face of a cooling roller 47 may be countered, it is desirable to have two or more discharge sections in which only predetermined spacing was detached and prepared along the direction of an axis of a cooling roller. The width of face (width of face of one flow of a molten metal) of this discharge section is set as 5mm - 30mm, and is more suitably set as 7mm - 20mm. The width of face of the flow of a molten metal tends to spread in a longitudinal direction as it separates from the location of the above-mentioned discharge section, but when preparing two or more

discharge sections in chute 45 and forming two or more molten metal flow, it is desirable to make it the adjoining molten metal flow not contact mutually. Thus, the effectiveness of reducing thickness dispersion of a quenching alloy is heightened, enlarging the molten metal amount of supply as the whole by forming two or more molten metal flow in abbreviation parallel, and regulating the width of face of each molten metal flow.

[0055] Along the direction of an axis of a cooling roller 47, the molten metal 43 supplied on the chute 45 has the width of face and abbreviation same width of face of each discharge section, and contacts a cooling roller 47. Then, the molten metal 43 which contacted by predetermined tapping width of face moves a roll (enabling it to pull up to cooling roller 47) peripheral surface top to a cooling roller 47 with rotation of a cooling roller 47, and it is cooled in this migration process. In addition, in order to prevent molten metal leakage, as for the distance between the point of chute 45, and a cooling roller 47, it is desirable to be set as 3mm or less (especially the range of 0.4-0.7mm).

[0056] With [heat treatment] book operation gestalt, heat treatment is performed in argon atmosphere. Preferably, a programming rate is carried out in 5 degrees C/second - 20 degrees C/second, and at 550-degree-C or more temperature of 850 degrees C or less, 30 seconds or more, after [20 or less minutes] carrying out time amount maintenance, it cools to a room temperature. Of this heat treatment, into a residual amorphous phase, the fine crystal of a metastable phase deposits and grows and nano composite organization is formed.

According to this invention, since the detailed R2Fe14B crystal phase (Nd2Fe14B mold crystal phase) has already existed more than the whole 60 volume % at the time (as-cast) before initiation of heat treatment, big and rough-ization of an alpha-Fe phase or other crystal phases is controlled, and each configuration phase other than a Nd2Fe14B mold crystal phase (soft magnetism phase) is made detailed by homogeneity. The rate of a volume ratio which the R2Fe14B crystal phase after heat treatment (Nd2Fe14B mold crystal phase) occupies in an alloy is 65 - 85%.

[0057] In addition, if heat treatment temperature is less than 550 degrees C, an amorphous phase may remain and after heat treatment may not reach level with sufficient coercive force depending on quenching conditions. Moreover, if heat treatment temperature exceeds 850 degrees C, grain growth of each configuration phase will be remarkable, a residual magnetic flux density B_r will fall, and the square shape nature of a demagnetization curve will deteriorate. For this reason, although 550 degrees C or more 850 degrees C or less of heat treatment temperature are desirable, the range of more desirable heat treatment temperature is 570 degrees C or more 820 degrees C or less.

[0058] In this invention, it deposits uniformly [the $Nd_2Fe_{14}B$ mold compound phase of amount sufficient in a quenching alloy], and minutely. For this reason, even when not daring perform heat-of-crystallization processing to a quenching alloy, the rapid solidification alloy itself can demonstrate sufficient magnet property. Therefore, although heat-of-crystallization processing is not a process indispensable to this invention, in order for it to be improvement in a magnet property to perform this, it is desirable. In addition, it is possible for heat treatment of low temperature to also fully raise a magnet property as compared with the former.

[0059] A heat treatment ambient atmosphere has desirable inert gas, such as Ar gas of 50 or less kPas, and N_2 gas, in order to prevent oxidation of an alloy. 1. You may heat-treat in the vacuum of 0 or less kPa.

[0060] In the quenching alloy before heat treatment, metastable phases, such as Fe_3B phase, a $Fe_{23}B_6$ phase, and an $R_2Fe_{23}B$ three phase circuit, may be contained in addition to the $R_2Fe_{14}B$ phase and the amorphous phase. In that case, by heat treatment, an $R_2Fe_{23}B$ three phase circuit can disappear, and can carry out crystal growth of the iron machine boride (for example, $Fe_{23}B_6$) and α -Fe which show the saturation magnetization of $R_2Fe_{14}B$ phase, equivalent, or saturation magnetization higher than it.

[0061] In a final magnet alloy, an $R_2Fe_{14}B$ ($R_2T_{14}Q$) mold compound phase is contained below 85 volume % more than 65 volume % through heat treatment.

When R concentration is nine atoms %, the rate of a volume ratio of an R2T14Q mold compound phase is specifically about 75% of the whole, and when R concentration is eight atoms %, the rate of a volume ratio of an R2T14Q mold compound phase is about 68% of the whole. On the other hand, a soft magnetism phase is contained below 35 volume % more than 10 volume % in a magnet.

[0062] Moreover, the rate of a volume ratio of all the crystal phases containing an R2T14Q mold compound or ferromagnetic iron machine boride is 95% or more of the whole, and the rate of a volume ratio of an amorphous phase is 5% or less of the whole.

[0063] When a magnet is produced using the quenching alloy by this invention, even if a soft magnetism phase like iron machine boride finally exists, since the soft magnetism phase exists in the surroundings of a hard magnetism phase thinly or finely, the magnetic properties which each configuration phase joined together magnetically by the exchange interaction, and were excellent are demonstrated.

[0064] When a magnet is produced using the quenching alloy by this invention, ***** of a grain boundary phase consists of ferromagnetic iron machine borides (Fe3B, Fe23 B6, etc.), and ferromagnetic alpha-Fe is contained as other phases. Specifically, the rate of a volume ratio of the iron machine boride occupied to a grain boundary phase is 70% or more. On the other hand, the rare earth elements R, such as Nd, hardly exist in a grain boundary phase, but are used effective in generation of a hard magnetism phase. It will not be obtained without adding a suitable quantity of Ti in the presentation field to which such organization has few presentation ratios x of R than 10 atom %, and the presentation ratio x of Q exceeds 10 atom %. When other metallic elements are added, even if a grain boundary phase is formed instead of adding Ti, the thing with magnetization low [the grain boundary phase] for which it is easy to become amorphous and the property of a nano composite magnet is demonstrated will be difficult. Moreover, when Ti is added and the presentation

ratio x of Q is below 10 atom %, the high soft magnetism phase of magnetization is not formed in a grain boundary, and it does not become the nano composite magnet which discovers a magnet property by the switched connection of a composite interphase.

[0065] In addition, the diameter of average crystal grain of the R2T14Q mold compound phase after heat treatment needs to be set to 300nm or less which is a diameter of single domain crystal grain, it is desirable that it is [20nm or more] 200nm or less, and it is still more desirable that it is [20nm or more] 100nm or less.

[0066] On the other hand, if the average thickness of the iron machine boride phase formed in the shape of a film exceeds 50nm, since the exchange interaction committed to each configuration interphase will become weaker and the square shape nature of a demagnetization curve will deteriorate, (BH) max will fall. As for the average size (average thickness of a film) of the iron machine boride phase measured along the thickness direction of a grain boundary or a subgrain boundary from the above thing, it is desirable that it is 50nm or less. As for the above-mentioned average size of an iron machine boride phase, it is still more desirable that it is 30nm or less, and it is most desirable that it is 20nm or less.

[0067] In addition, the thin band of a quenching alloy may be coarsely cut or ground before heat treatment. If the obtained magnet is pulverized after heat treatment and magnet powder (magnetic powder) is produced, various bond magnets can be manufactured according to a well-known process from the magnetic powder. When producing a bond magnet, it is mixed with an epoxy resin or Nylon and iron machine rare earth alloy magnetic powder is fabricated by the desired configuration. At this time, other magnetic powder, for example, Sm-Fe-N system magnetic powder, and hard ferrite magnetic powder of a class may be mixed to nano composite magnetic powder.

[0068] Various kinds of rotating machines, such as a motor and an actuator, can be manufactured using an above-mentioned bond magnet.

[0069] When using the ***** end of this invention for injection-molding bond magnets, it is desirable to grind so that average grain size may be set to 200 micrometers or less, and the mean particle diameter of more desirable powder is 30 micrometers or more 150 micrometers or less. Moreover, when using for compression-molding bond magnets, it is desirable to grind so that grain size may be set to 300 micrometers or less, and the mean particle diameter of more desirable powder is 30 micrometers or more 250 micrometers or less. Furthermore, the desirable range is 50 micrometers or more 200 micrometers or less.

[0070] In addition, the moldability at the time of bond magnet shaping, the corrosion resistance of the bond magnet obtained, and thermal resistance are improvable by performing surface preparation, such as coupling processing, chemical conversion, and plating, to the front face of the magnet powder by this invention. Moreover, as well as powdered surface preparation when surface preparation, such as resin paint, and chemical conversion, plating, is performed to the bond magnet front face after shaping, the corrosion resistance and thermal resistance of a bond magnet can be improved.

[0071] The whole quantity consists of B (boron), or the [reason for limitation of a presentation] Q consists of combination of B and C (carbon). As for the rate of C to the total amount of Q, it is desirable that it is 0.25 or less.

[0072] If the presentation ratio x of Q becomes below 10 atom %, it becomes difficult to produce the quenching alloy with which an $R_2Fe_{14}B$ mold crystal phase and an amorphous phase are intermingled, and when the cooling rate at the time of quenching is comparatively low in 102 degrees C/second - about 104 degrees C/[a second and], even if it heat-treats after that, only H_cJ of less than 400 kA/m will be obtained. Moreover, also in a melt quenching method, it becomes impossible for process costs to adopt the comparatively cheap strip cast method, and the price of a permanent magnet will rise. On the other hand, if the presentation ratio x of Q exceeds 20 atom %, since a deposit of iron machine boride will begin at the deposit and coincidence term of $R_2Fe_{14}B$ phase, iron

machine boride will make it big and rough. Consequently, the nano composite organization where the iron machine boride phase spread distribution or in the shape of a film in the grain boundary or subgrain boundary of $R_2Fe_{14}B$ at homogeneity is not obtained, but magnetic properties deteriorate.

[0073] It is desirable to set up so that the presentation ratio x of Q may exceed 10 atom % and it may consist of the above thing below 20 atom %. The upper limit of the more desirable presentation ratio x is 17 atoms %, and the upper limit of the still more desirable presentation ratio x is 15 atoms %.

[0074] In addition, the ratio p of C to the whole Q is an atomic ratio, and it is desirable that it is in or more 0.025 or less range. In order to acquire the effectiveness of C addition, it is desirable that the ratio p of C is 0.01 or more. If there is too less p than 0.01, the effectiveness of C addition will hardly be acquired. On the other hand, if p becomes larger than 0.25 too much, the amount of generation of an α -Fe phase will increase, and the problem that magnetic properties deteriorate will arise. As for the minimum of a ratio p , it is desirable that it is 0.02, and, as for the upper limit of p , it is desirable that it is 0.20 or less. As for a ratio p , it is still more desirable that it is [or more 0.08] 0.15 or less.

[0075] R is one or more sorts of elements chosen from the group of rare earth elements (an yttrium is included). If La or Ce exists, since coercive force and square shape nature will deteriorate, it is desirable that La and Ce are not included substantially. However, when La and Ce (below 0.5 atom %) of a minute amount exist as an impurity mixed unescapable, it can be said that it does not contain substantially satisfactory on magnetic properties. As for R , it is desirable that Pr or Nd is included as an essential element, and, more specifically, it may permute a part of the essential element by Dy and/or Tb . When the presentation ratio y of R becomes under the whole 6 atom %, the compound phase which has the $R_2Fe_{14}B$ mold crystal structure required for the manifestation of coercive force does not fully deposit, but it becomes impossible to acquire the coercive force H_{cJ} of 480 or more kA/m. Moreover, if the presentation ratio y of R becomes more than 10 atom %, the iron machine boride which has

ferromagnetism, and the abundance of α -Fe will fall. Therefore, as for the presentation ratio y of rare earth elements R, it is desirable to adjust the more than range under of 10 atom %, for example, 7 atom %, below to 9.5 atom % more than 6 atom %. The upper limit of the range of 9.3 atoms % and still more desirable R of the upper limit of the range of more desirable R is 9.0 atoms %. The minimum of the range of desirable R is 8.0 atoms %, and the minimum of the still more desirable range of R is 8.3 atoms %. At this invention, although the concentration of R is low in this way, in order that $R_2Fe_{14}B$ phase may deposit and grow by work of Ti more preferentially than other phases, R in an alloy molten metal is used effective in generation of $R_2Fe_{14}B$ phase, and R is low-concentration-ized in a grain boundary part. consequently, it becomes below 0.5 atom %, and R concentration in a grain boundary phase is markedly alike as compared with R concentration in a hard magnetism phase (11 atom % extent), and becomes low. Since R does in this way and is effectively used for formation of a hard magnetism phase ($R_2Fe_{14}B$ phase), although there are few presentation ratios of R than 10 atom % and the rate of a volume ratio of a hard magnetism phase ($R_2Fe_{14}B$ phase) becomes below 85 atom % more than 65 atom %, by this invention, the hard magnetic property which was excellent with switched connection with the soft magnetism phase which exists in a grain boundary is discovered. In addition, the rate of a volume ratio of configuration phases, such as $R_2Fe_{14}B$ phase in this specification, is the value measured by Messbauer spectrum spectroscopy.

[0076] Ti is an indispensable element in order to acquire the effectiveness mentioned above, it contributes to the improvement of the improvement in coercive force H_cJ and a residual magnetic flux density B_r , and the square shape nature of a demagnetization curve, and raises maximum energy product $(BH)_{max}$.

[0077] If the presentation ratio z of Ti becomes under the whole 0.1 atom %, the effectiveness of Ti addition will not fully be discovered. On the other hand, if the presentation ratio z of Ti exceeds the whole 12 atom %, it will be easy to invite

the fall of a residual magnetic flux density B_r . As for the presentation ratio z of the above thing to Ti, it is desirable to consider as the range below 12 atom % more than 0.1 atom %. The minimum of the range of more desirable z is 1.0 atoms %, and the upper limit of the range of more desirable z is eight atoms %.

Furthermore, the upper limit of the range of desirable z is six atoms %.

[0078] Moreover, since the amorphous phase which contains Q (for example, boron) superfluously is easy to be formed so that the presentation ratio x of Q is high, it is desirable to make the presentation ratio z of Ti high. The compatibility of Ti over B is strong and it is condensed by the grain boundary of a hard magnetism phase. If the ratio of Ti to B is too high, since TiB_2 which is nonmagnetic is deposited, un-arranging [that magnetization falls] arises. On the other hand, if the ratio of Ti to B is too low, many nonmagnetic B rich amorphous phases will be generated. According to the experiment, it is desirable to adjust a presentation ratio so that $0.05 \leq z/x \leq 0.4$ may be satisfied, and it is more desirable to satisfy $0.1 \leq z/x \leq 0.35$. Furthermore, it is $0.13 \leq z/x \leq 0.3$ preferably.

[0079] Although Fe occupies the content remainder of an above-mentioned element, even if it permutes a part of Fe by a kind of Co and nickel, or two sorts of transition-metals elements (T), it can obtain desired hard magnetic property. If the amount of permutations of T to Fe exceeds 50%, the high residual magnetic flux density B_r beyond 0.7T will not be obtained. For this reason, as for the amount of permutations, it is desirable to limit to 50% or less of range 0% or more. In addition, since the Curie temperature of $R_2Fe_{14}B$ phase rises while the square shape nature of a demagnetization curve improves by permuting a part of Fe by Co, thermal resistance improves. The range where the amount of Fe permutations by Co is desirable is 40% or less 0.5% or more.

[0080] In order to acquire various effectiveness, a metallic element M may be added in the range of 0 - 10 atom % extent. M is one or more sorts of elements chosen from the group which consists of aluminum, Si, V, Cr, Mn, Cu, Zn, Ga, Zr, Nb, Mo, Hf, Ta, W, Pt, Pb, Au, and Ag.

[0081] As explained above, in this invention, most big and rough alpha-Fe is not deposited in a quenching alloy, and the organization which has a detailed R2T14Q mold compound phase or the organization which has a detailed R2T14Q mold compound phase, and the organization where the amorphous phase was intermingled are produced. Not only the phase constituted by only the part in which atomic arrangement carried out disordering to the "amorphous phase" in this specification completely but the phase which contains partially the precursor, the microcrystal (size: several nm or less), or the atomic cluster of crystallization shall be included. Specifically, the phase which can identify the crystal structure clearly neither by the X diffraction nor transmission electron microscope observation will be widely called an "amorphous phase." And suppose that the structure where the crystal structure can be clearly identified by the X diffraction or transmission electron microscope observation is called a "crystal phase."

[0082] If the alloy molten metal which has the presentation (namely, presentation excluding Ti from the presentation of this invention) which is similar so that the target presentation of this invention was cooled comparatively slowly conventionally, since the alloy organization where alpha-Fe deposited mostly would be obtained, there was a problem that alpha-Fe will make it big and rough by subsequent heat-of-crystallization processing. If soft magnetism phases, such as alpha-Fe, make it big and rough, a magnet property will deteriorate greatly and the permanent magnet which is equal to practical use will not be obtained at all.

[0083] Only when Ti is added, a hard magnetism phase deposits and grows more preferentially than other phases, and ferromagnetic iron machine boride deposits in the grain boundary of the main phase crystal grain. And the depositing iron machine boride joins together partially, a continuous film is formed, and the organization where the front face of the main phase crystal grain was thinly covered with the film is formed.

[0084] In addition, when it replaces with Ti and metallic elements, such as Nb, V,

and Cr, are added, as a result of grain growth of an alpha-Fe phase advancing remarkably in a comparatively high temperature field in which an alpha-Fe phase deposits and the magnetization direction of an alpha-Fe phase no longer being effectively restrained by switched connection with a hard magnetism phase, the square shape nature of a demagnetization curve falls greatly. Moreover, if it heat-treats in the comparatively low temperature field in which alpha-Fe does not deposit when it replaces with Ti and Nb, Mo, and W are added, it is possible to obtain the good hard magnetic property excellent in the square shape nature of a demagnetization curve. However, with the alloy which heat-treated at such temperature, it is presumed that the $R2Fe14B$ mold fine crystal phase distributes and exists in a nonmagnetic amorphous phase, and the structure of a nano composite magnet is not formed. Furthermore, if it heat-treats at high temperature, an alpha-Fe phase will deposit out of an amorphous phase. Unlike the case where Ti is added, after a deposit, this alpha-Fe phase grows rapidly and is made big and rough. For this reason, the magnetization direction of an alpha-Fe phase will no longer be effectively restrained by switched connection with a hard magnetism phase, and the square shape nature of a demagnetization curve will deteriorate greatly.

[0085] Moreover, since these addition metals dissolve easily to Fe and join together in antiferromagnetism compared with Ti when it replaces with Ti and V and Cr are added, magnetization will fall greatly.

[0086] When Ti is added unlike each above-mentioned element, in order that the kinetics (kinetics) of a deposit and growth of an alpha-Fe phase may become late and a deposit and growth may take time amount to it, before a deposit and growth of an alpha-Fe phase are completed, it is thought that a deposit and growth of $Nd2Fe14B$ phase begin. For this reason, before an alpha-Fe phase makes it big and rough, $Nd2Fe14B$ phase grows greatly in the condition of having distributed to homogeneity.

[0087] Thus, only when Ti is added, big and rough-ization of an alpha-Fe phase is controlled appropriately, and it becomes possible to form ferromagnetic iron

machine boride. Furthermore, in order for Ti to delay crystallization of Fe primary phase (gamma-Fe which metamorphoses into alpha-Fe behind) at the time of liquid quenching, to consider as the element which makes generation of a supercooled liquid easy and to carry out important work with boron and carbon, Even if it makes the cooling rate at the time of quenching an alloy molten metal into the comparatively low value of 102 degrees C/second - about 104 degrees C/second It becomes possible to produce the quenching alloy (for iron machine boride to be included in addition to an R2Fe14B mold crystal phase) which contains an R2Fe14B mold crystal phase more than 60 volume %, without depositing big and rough alpha-Fe.

[0088]

[Example] Weighing capacity was carried out so that a total amount might become 5k g using the ingredient of C, B, Fe, Co, Nb, Ti, and Nd of 99.5% or more of purity, and it supplied in the crucible made from an alumina so that it might have the alloy presentation shown in following Table 1.

[0089]

[Table 1]

		合金組成 (at%)	ロール周速度 (m/s)	噴射圧 (kPa)
実施例	No. 1	$\text{Nd}_{8.5}\text{Fe}_{61}\text{Co}_2\text{B}_{11}\text{C}_1\text{Ti}_{2.5}$	9	30
	No. 2	$\text{Nd}_9\text{Fe}_{61}\text{B}_{13}\text{C}_1\text{Ti}_4\text{Nb}_1$	10	30
	No. 3	$\text{Nd}_{7.5}\text{Fe}_{61}\text{B}_{12}\text{C}_1\text{Ti}_4$	9	30
比較例	No. 4	$\text{Nd}_9\text{Fe}_{61}\text{B}_{13}\text{C}_1\text{Ti}_4\text{Nb}_1$	7	6

[0090] Sample No.1-3 are the example of this invention, and sample No.4 are an example of a comparison.

[0091] Since the product made from an alumina has the orifice made from BN with a diameter of 2.8mm at the pars basilaris ossis occipitalis, after dissolving within the crucible made from an alumina, the above-mentioned raw material serves as an alloy molten metal, and will be caudad discharged from an orifice. The pressure performed the dissolution of a raw material using the high-frequency-heating method to the bottom of the argon atmosphere of 35kPa(s). In

this example, molten metal temperature was set as 1500 degrees C.

[0092] Moreover, differential pressure was set to 30kPa(s) and the molten metal was made to blow off [in the example] to the peripheral face of the copper roll in the location of 0.7mm of lower parts of an orifice by pressurizing the surface of hot water of an alloy molten metal by argon gas so that differential pressure may serve as 15kPa(s) in the example of a comparison. A roll rotates at high speed, while the interior is cooled so that the temperature of the peripheral face may be maintained by room temperature extent. For this reason, the alloy molten metal which blew off from the orifice will be flown in the peripheral-velocity direction, contacting a roll peripheral surface and heat being taken. In order to spout an alloy molten metal on a roll peripheral surface continuously through an orifice, the alloy solidified by quenching will have the gestalt of the ribbon prolonged for a long time in thin band-like one.

[0093] In the case of the roll kneader method (the single rolling method) adopted by this example, a cooling rate is prescribed by roll peripheral velocity and the amount of molten metal flowing down per unit time amount. It depends for this amount of molten metal flowing down on the diameter of an orifice (cross section), and the molten-metal-pressure force. In this example, the molten metal supply rate was considered as a part for 3.0-5.0kg/, and roll surface velocity was set [second] up in 9-10m /. On the other hand, in the example of a comparison, by making injection pressure low, the molten metal supply rate was lowered [minute] in about 1kg /, and roll surface velocity was set [second] up in 7m /.

[0094] In this way, the result of having measured the thickness of the obtained quenching alloy is shown in Table 2, Table.3, and drawing 4 . Measurement of thickness followed each of 100 fragments of a quenching alloy thin band using the micro gage of both the spherical surfaces. The size of each fragment was about 2mm in die-length:5-20mmx width of face.

[0095]

[Table 2]

急冷合金厚さ (μm)	実施例			比較例
	No. 1	No. 2	No. 3	No. 4
平均値	75.6	67.1	74.4	85.9
最大値	110	97	115	144
最小値	62	48	51	61
標準偏差	8.354	10.173	11.296	16.636

[0096]

[Table 3]

急冷合金厚さ (μm)	実施例			比較例
	No. 1	No. 2	No. 3	No. 4
40 以上 50 未満	0	0	0	0
50 以上 60 未満	0	25	8	0
60 以上 70 未満	24	36	28	15
70 以上 80 未満	55	23	33	27
80 以上 90 未満	15	12	24	23
90 以上 100 未満	5	2	6	26
100 以上 110 未満	1	0	0	3
110 以上 120 未満	0	0	1	2
120 以上 130 未満	0	0	0	2
130 以上 140 未満	0	0	0	1
140 以上 150 未満	0	0	0	2

[0097] Compared with the low example of a comparison of a molten metal supply rate, thickness dispersion of an example is very small so that the above result may show.

[0098] When the characteristic X ray of CuK α investigated the organization of the quenching alloy obtained by the above-mentioned quenching approach, the diffraction peak of Nd₂Fe₁₄B was slightly observed in the halo pattern. This checked that detailed Nd₂Fe₁₄B existed in an amorphous phase in the quenching alloy. Compared with the example, the diffraction peak of Nd₂Fe₁₄B in the example of a comparison was more strong.

[0099] Next, the above-mentioned quenching alloy was heat-treated in argon gas. After holding a quenching alloy for 6 minutes at 740 degrees C, it cooled to the room temperature. Then, the magnetic properties of each sample were measured using the oscillatory type magnetometer. The following table 4 shows this measurement result.

[0100]

[Table 4]

		B, (T)	H _{cu} (kA/m)	(BH) _{max} (kJ/m ³)
実施例	No. 1	0.88	762.3	120.6
	No. 2	0.80	1027.4	108.3
	No. 3	0.82	597.1	103.2
比較例	No. 4	0.73	982.0	64.3

[0101] as shown in Table 4, compared with an example, it is markedly alike, and maximum energy product (BH) max of the example of a comparison is low, and its residual magnetic flux density Br is also low.

[0102] Next, when the characteristic X ray of CuKalpha investigated change of the configuration phase after heat treatment, the halo pattern seen before heat treatment disappeared, and it checked in the example that the mixed organization which mainly contains Nd₂Fe₁₄B and Fe₂₃ B₆ was formed by each. On the other hand, in addition to Nd₂Fe₁₄B and Fe₂₃ B₆, existence of alpha-Fe was checked in the example of a comparison.

[0103] Furthermore, when the detailed metal texture after heat treatment was observed with the transmission electron microscope (TEM), in the example, crystal grain with a mean particle diameter of about 40nm and the about 10nm fine crystal grain located in the grain boundary existed. On the other hand, in the example of a comparison, the diameter of average crystal grain was relatively large. The diameter of average crystal grain and standard deviation of Nd₂Fe₁₄B crystal grain are shown in Table 5 about each sample.

[0104]

[Table 5]

	実施例			比較例
	No. 1	No. 2	No. 3	No. 4
平均結晶粒徑(nm)	35	24	45	51
標準偏差(nm)	10.71	6.29	11.26	16.78

[0105] as shown in Table 5, compared with the example of a comparison, an organization is detailed in the example -- and it is equalizing. In case this cools an alloy molten metal and produces a quenching alloy, it is because uniform cooling was performed in the example.

[0106]

[Effect of the Invention] In case quenching of the alloy molten metal which added Ti is performed according to this invention, even if it produces a comparatively thick quenching alloy by enlarging a molten metal supply rate compared with the former, the thickness dispersion can be suppressed small and a quenching alloy with a uniform organization can be offered. By using such a quenching alloy, the nano composite magnet which was excellent in the property can be manufactured.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] (a) And (b) is drawing showing typically the organization of the iron machine alloy magnet by this invention.

[Drawing 2] (a) is the sectional view showing the whole equipment example of a configuration used for the approach of manufacturing the quenching alloy by this invention, and (b) is an enlarged drawing of a part with which rapid solidification is performed.

[Drawing 3] It is drawing showing the configuration of the strip cast equipment which can be used for manufacture of the quenching alloy by this invention.

[Drawing 4] It is the graph which shows the thickness distribution of a quenching alloy.

[Description of Notations]

1b, 2b, 8b and 9b Controlled atmosphere feed hopper

1a, 2a, 8a, and 9a Flueing opening

1 Dissolution Room

2 Quenching Room

3 Fusion Furnace

4 Hot-Water-Storing Container

5 Tapping Nozzle

6 Funnel

7 Rotation Cooling Roller

21 Molten Metal

22 Alloy Thin Band

41 Fusion Furnace

43 Alloy Molten Metal

45 Chute (Guidance Means)

47 Cooling Roller

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